UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC MODEL STUDIES OF THE SPILLWAY AND OUTLET WORKS FOR ANDERSON RANCH DAM

BOISE PROJECT–IDAHO

Hydraulic Laboratory Report No. Hyd-217

BRANCH OF DESIGN AND CONSTRUCTION
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CONTENTS

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Branch of Design and Construction
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Hydraulic Laboratory Report No. 217
Hydraulic Laboratory
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Subject: Hydraulic model studies of the spillway and outlet works for Anderson Ranch Dam--Boise Project.

INTRODUCTION

Anderson Ranch Dam is a rock and earthfill structure, approximately 336 feet high, located about 45 miles southeast of Boise, Idaho, on the south fork of the Boise River, Figure 1. The reservoir formed by the dam will be about 15 miles long and will have a storage capacity of 500,000 acre-feet.

The spillway, with a maximum capacity of 20,000 second-feet, will be controlled by two 25-foot by 22-foot radial gates mounted to seat on a low ogee section at the entrance. The five outlets through the dam will be controlled by five 72-inch hollow-jet valves having a total maximum capacity of 10,000 second-feet. These outlets will be used for the regulation of the reservoir level and river flow downstream and, during periods of flood flow, will be used to supplement the spillway. The spillway and outlet works constitute a combination structure in which the spillway flow shoots over the openings for the outlet valves and plunges into a stilling-pool a short distance downstream. The outlet valves discharge under the spillway flow and into the same stilling-pool. The pool was intended to operate satisfactorily for:

a. Any combination of valves operating with no discharge from the spillway.

b. Any combination of valves operating and any flow up to maximum over the spillway.

c. Any flow over the spillway up to maximum without the valves discharging.

The model studies were made for the purpose of determining the proper pool to satisfy these requirements; to select the most desirable spillway entrance; and to check the wall heights and shape of the spillway chute.

Other model studies made by this laboratory on Anderson Ranch Dam are: "Model Studies for Development of a Hollow-jet Valve for Anderson Ranch Dam," by Fred Locker, Hydraulic Laboratory Report No. 148, September 12, 1944, and "Hydraulic Model Studies for the Initial Regulation of Water at Anderson Ranch Dam," by Fred Locker, Hydraulic Laboratory Report No. 153, September 26, 1944.

SUMMARY

In the course of the model studies, seven different arrangements of stilling-pools were tested. Each pool arrangement was tested with various combinations of dentated sills and apron teeth with the pool walls either sloped or vertical and with various length piers for stabilizing the pool when the valves were discharging.

Tests were made of five different entrances and two types of crests; one crest located at elevation 4172; the other at 4174. In addition, studies were made to determine the best location and shape of the spillway chute walls.

Of the five types of entrances tested, the one shown on Figure 2 was selected for the final design, principally because of structural advantages rather than for superior hydraulic performance. In general, flow in all five entrances was satisfactory. Some indicated slightly more head loss than others, but the difference was not sufficient to warrant a choice on the hydraulic performance alone.

The spillway chute walls, as shown on Figure 2, were located by adjusting the wall location and the warp from the gate section until the most favorable cross-sectional water surface was obtained for all gate combinations.

The major part of the model studies consisted of tests to determine the most suitable stilling-pool for the combined spillway and outlet flows or any combination thereof. This part of the study involved testing seven different pool profiles in combination with different valve spacings, several types of pier walls, different types of apron teeth and pool sills, and various pool wall slopes from vertical to 1:1. The 41 stilling-pool combinations studies are listed in Table I at the back of the report. Design No. 4, Figure 3, was chosen as the recommended design after all other design factors were considered. It consisted of vertical stilling-pool walls, Type D sill (Figure 3), Type C apron teeth (Figure 3), and Type VI pier walls (Figure 4) on 20-foot centers. In general, the recommended design, as determined from the model, is the same as that shown on Figure 2, except that the equation of the apron profile below the outlet valve was changed from $-Y = \frac{X^2}{900}$ to $-Y = \frac{X^2}{1253}$. This was done to make the apron profile conform to data obtained from later tests with the hollow-jet valves.

THE MODELS

Model on 1:48 Scale

Two models were used in the study, one a composite structure of both the spillway and outlet works on a 1:48 scale, and the other a model of the outlet works only on a 1:24 scale. The details of the 1:48 scale model are shown on Figure 5. The headbox was constructed of rough lumber and lined with lightweight sheet metal to prevent leakage of water. The box contained an intake pipe and a rock baffle to still the flow before it entered the model intake. The reservoir contours, in the vicinity of the spillway, were placed in the headbox, and the intake, constructed of concrete and sheet metal, was also installed in the box. The gate section and crest were made of redwood. The spillway chute consisted of a frame supporting a plywood floor and redwood sidewalls. The transition from the vertical walls at the gate section to the sloping walls of the chute was effected by a warp consisting of a mixture of concrete and plaster of Paris. The stilling-pool, apron teeth, and dentates were also constructed of redwood. A tailbox, constructed similar to the headbox, was placed at the downstream end of the model and contained the stilling-basin for the spillway and outlet works and a representative part of the river in the immediate vicinity.

The flood-control outlets consisted of five brass valves made to simulate the flow from a hollow-jet valve. These valves, 1.5 inches in diameter, were connected by rubber tubing to a 12-inch diameter manifold which, in turn, was connected by a 6-inch line to the headbox. This arrangement did not give a representative pattern of flow from the valves except when all were operating fully open. Even then the representation was not exact because of peculiarities in the prototype which would cause the latter valves to discharge unequal amounts of water when all were operating fully open. The model arrangement was more conducive to producing equal flow through each valve. As the writer did not conduct these tests, it is not known whether this fact was overlooked, or if it was assumed that the model would be sufficiently accurate without correction for unequal discharge.

The reservoir elevation in the headbox was measured with a hookgage mounted in a stilling-well. A water column connected to a piezometer opening in the tailbox was used to measure tailwater elevations.

Model on 1:24 Scale

Subsequent to the tests on the 1:48 model, a 1:24 model of the outlet works and stilling-pool, as recommended from the 1:48 model, was constructed for the purpose of checking the results from the 1:48 model. In this model, five 3-inch adjustable hollow-jet valves were used for regulating the outlet flow. These valves were geometrically similar to the 72-inch prototype hollow-jet valve described in Hydraulic Laboratory Report No. 148.

THE SPILLWAY

Intake Studies

The original intake, as shown on Figure 6, was satisfactory from a hydraulic standpoint. There were small ripples present on the north side of the intake section near the upstream end of the concrete lining. These seemed to have little effect on the flow. They probably were caused by surface tension in the model and were not the result of a deficiency in design.

At this point in the testing program, the spillway length was increased for structural reasons, a procedure which resulted in an unfavorable location of the original intake design. Accordingly, the design was revised as shown on Figure 7A, and found to be satisfactory. The ripples were still present on the north side of the intake, as was a slight drawdown in water surface due to a higher acceleration of flow in the narrower section. An attempt was made to rectify the drawdown by flattening the sideslopes, thus increasing the approach area and decreasing the velocity of approach. Some improvement was obtained in that the magnitude of the ripples and drawdown was decreased.

With the length of the spillway increased, it was now possible to raise the spillway crest 2 feet and obtain the same discharge. It was anticipated that raising the crest would improve the flow in the approach channel, since the slope on the north side could be flattened still more to provide additional approach area. This was verified in the model; however, the size of the ripples and drawdown was decreased only a slight amount.

Although Design I was considered satisfactory, it later appeared that by revising the inlet still more, it might be possible to remove the reverse curve in the roadway at the crest of the dam. Two designs, shown on Figures 7B and C, were tested with this in view, but both showed excessive drawdown caused by restricting the area of the approach channel.

It was concluded that this drawdown would be present unless the right side of the channel extended to a point where the bottom of the channel was below elevation 4169.0. At this point, the natural ground surface slopes downward which would provide a better channel approach. Actually, the drawdown in water surface under these conditions still would be present but it would occur more gradually due to a more gradual acceleration of flow. There would be no real gain in head, but only an improvement in the appearance of the water surface.

This type of inlet would have detracted from the appearance of the structure as well as adding to the cost. In view of the fact that it did not add to the hydraulic properties of the structure, the design was abandoned in favor of that shown in Figure 2 which was finally recommended.

Chute Studies

This part of the study consisted of adjusting the transition from the gate section to the chute walls, and adjusting the chute walls until a satisfactory distribution of flow was obtained. This was accomplished by using rubber mats to form the chute sidewalls and adjusting the location of the mats until the best distribution of flow was obtained in the chute for the most adverse flow conditions. This condition was usually obtained with flow from one gate only. After the location of the walls was determined, the rubber mats were replaced with redwood walls. Water surface cross-sections were then taken to show the distribution of flow in the chute, and are shown on Figure 8. This figure also shows a comparison of the distribution of flow at the end of the chute, Station 12+55.91 with both gates discharging 10,000 and 20,000 second-feet, and one gate discharging 10,000 second-feet. These cross-sections indicate good distribution of flow in all cases. The cross-sections indicate that the wall arrangement, shown on Figure 2, will give satisfactory distribution under the most adverse operating conditions.

STILLING-POOL STUDIES

Original Design

The design, shown on Figure 6, is considered the original design since it was the first to be tested in the model. Actually, the original design had a different spillway entrance, a shorter crest, and the outlet valves were spaced at 18-foot centers. During the construction of the model, changes were made in the prototype design, so the model was changed to conform to the latest design before testing began.

The model as first tested, Figure 6, included the chute extension indicated on the drawing, outlet valves spaced at 20-foot centers, and 1/4:1 sloping pool walls. A Type A sill, Figure 3, was placed at the downstream end of the stilling-pool. Visual observations of the flow in the pool showed an unstable jump when the valves were discharging alone. This is evident from Figure 9A which shows the valves discharging at the maximum capacity of 10,000 second-feet. In this instance the flow from the pool was concentrated on one side with a vortex on the other. With flow over the spillway only, this condition of unsymmetry was not present, and neither was it apparent for the combined spillway and valve discharge. However, at the maximum combined valve and spillway discharge of 30,000 second-feet, the pool surface was very rough, with waves of considerable magnitude forming in the pool.

The scour caused by a flow of 30,000 second-feet was not excessive, but as shown on Figure 9B, indicates that the flow from the pool was not symmetrical even though this was not apparent from surface conditions. The photograph shows scour on the right side and a deposition of material on the left side looking downstream. This definitely indicates that a higher velocity existed on the right side of the pool than on the left.

The unbalanced flow in the pool for both conditions of operation can be attributed to the sloping sidewalls of the stilling-pool. This condition was rectified in the model by replacing the sloping pool walls with vertical walls as shown in Figure 10A. The vertical walls balanced the flow in the pool and produced a symmetrical scour pattern (Figure 10) for the same conditions of flow illustrated in Figure 9. The deposition of material at the center and immediately downstream of the pool, and the adjacent scour is the result of a combination of excessive pool exit velocities and the action produced by the sill. The sill tended to lift the flow from the bottom causing a low-pressure region immediately downstream, which would be devoid of water if there were no inflow to the region from the sides. This inflow, in combination with the vortices set up at the side by the high-exit velocities, had sufficient velocity to cause the scour. Deposition occurred when the two opposing sideflows met and turned downstream. In general, scour of this type is difficult if not impossible to eliminate entirely as long as a pool sill is used.

As the above results were not entirely satisfactory, the design was revised as shown in Figure 3 (revised Design No. 1) and tested with various lengths of pier walls, for no discharge over the spillway, and with both vertical and sloping pool walls in the combinations shown in Table 1, Design No. 1. The best results were obtained with Type I pier walls, (Figure 4), vertical pool walls, and the valves mounted level at 20-foot centers. The pier walls spaced between the valves stabilized the pool when less than five valves were operating. In the absence of the piers, less than five valves operating produced unsymmetrical flow with large vortices forming in the pool, resulting in poor energy dissipation. The longer the piers the greater was the stabilizing effect as the longer piers extended completely through the hydraulic jump. One group of tests in this design consisted of tilting the valves downward at an angle of two degrees and operating the valves with Types I, II, and III pier walls (Figure 4) in place. The tilting of the valves did not effect the energy dissipation, but tended to decrease the necessary length of the apron.

Design No. 1

Stilling-pool Design No. 1 was not tested with flow over the spillway. The tests on this design were confined entirely to studies of the valve flow and the dissipation of the jet energy. The only conclusion drawn from this part of the study was that piers would be necessary between the valves for unsymmetrical operation, and that they should be extended into the pool as far as possible.

Design No. 2

The stilling-pool profile shown on Figure 3 as Design No. 2, was developed to reduce the pool-exit velocity and thus reduce the scour downstream. The design was essentially the same as No. 1, except that it embodied a sharp break in the parabolic apron immediately upstream of the pool floor. It was thought that this might increase the efficiency of the energy dissipation but the tests did not confirm this. The step actually introduced a potential source of cavitation which more than offset any advantages that might be obtained from increased energy dissipation. As this design was not satisfactory, the model was revised as shown on Figure 3, Design No. 3.

Design No. 3.

Design No. 3 consisted of a long apron with a relatively short horizontal pool floor made intentionally to utilize the principle of obtaining a hydraulic jump on a sloping apron, even though the river depths were not compatible with the jump heights. The performance of this design was as anticipated. The jump formed on the apron at all discharges with either the valves or the spillway discharging. At the combined discharge of 30,000 second-feet, the pool was exceptionally rough and the velocity of the flow as it left the pool was abnormally high. As this was the case in all the previous designs tested, it became apparent that it would be necessary to lower the pool floor to obtain the desired energy dissipation and velocity in the stilling-pool.

Design No. 4

In Design No. 4 (Figure 3) the pool floor was lowered to elevation 3830.00, the walls were vertical, and Type IV piers (Figure 4) were used between the valves. A photograph of this arrangement is shown on Figure 11A.

This design showed an improvement in the flow in the stilling-pool and less scour in the channel immediately downstream. With only the valves discharging, the jump formed in the upstream part of the pool, Figure 11B, and the water surface was not as rough as in the previous designs. At the combined discharge of 30,000 second-feet, Figure 12A, the velocity of the water leaving the pool was reduced over previous designs, and the tendency to form side eddies in the river channel was nearly eliminated.

Before an entirely satisfactory solution to Design No. 4 was obtained, a considerable number of variations, shown on Table 1, were studied in the model. These consisted of varying the slope of the pool walls from vertical to 1:1, installing apron teeth, and changing the pool sill. It was shown conclusively in this series that as far as the Anderson Ranch Dam Design was concerned, the vertical walls produced the most satisfactory performance. The tests were conducted by starting with vertical walls and observing the flow in the pool for a particular discharge, then repeating the procedure for wall slopes of 1/8:1, 1/4:1, 3/8:1, 1/2:1, and 1:1. In each case the flow in the pool became less stable with each decrease in slope until, at the 1:1 value, severe eddies formed at each side of the pool and the main flow in the center was extremely unstable.

Up to this point, the Type IV piers were used on the stilling-pool apron. A better appearing and more economical structure could be obtained without upsetting the hydraulic characteristics of the structure, by altering the shape of the downstream ends of the piers. With this in view, five additional tests, shown on Table 1, were performed with Types V, VI, VII, VIII, and IX piers, Figure 4. From these tests, the Type VI pier was considered the most suitable and was recommended for the final design.

Designs Nos. 5, 6, and 7

Although stilling-pool Design No. 4 was tentatively selected as the recommended design, three other variations, described as Designs Nos. 5, 6, and 7 on Figure 3, were tested to determine if the design could be improved. The first of these tested, Design No. 5, embodied a reverse curve at the toe of the stilling-pool apron to help diffuse the apron jet and produce better energy dissipation. As far as could be determined from visual observations, there was little, if any, improvement over Design No. 4. The addition of apron teeth indicated some improvement. However, this design was basically unsound in that the reverse curve on the apron was a potential source of cavitation and pitting which might have caused damage to the prototype structure. For this reason the design was not given serious consideration.

Design No. 6 was similar to Design No. 4, except that the slope connecting the parabola to the pool floor was changed from 5:1 to 4:1. This changed the spread of the valve jets and increased the length of the pool floor without increasing the overall length of the structure. The change did not improve the performance of the pool over that obtained from Design No. 4. As lengthening the pool floor increased the cost of the structure, and as there was no improvement in performance, the design was not given further consideration.

Design No. 7 was also similar to Design No. 4, except that the pool floor was raised from elevation 3830 to 3835 as shown on Figure 3 and Table 1. This was an attempt to decrease the height of the stilling-pool walls and maintain the hydraulic performance of Design No. 4. The last was not successful as the pool "swept out" at much lower tailwater elevations than in the previous tests. Figure 13 shows the "sweep out" curves for Design No. 7 and Design No. 4 with and without apron teeth.

Recommended Design

The final design as determined from the model is shown on Figure 2, except that the equation of the parabola on the pool apron was changed from $-Y = \frac{X^2}{900}$ to $-Y = \frac{X^2}{1253}$. This change was the result of later tests on the Friant-Kern Canal outlets where the model tests with hollow-jet valves indicated that a different apron profile was desirable.

Piezometric pressures and water surface profiles were taken for the final design, Figure 14. These show positive pressures on the apron teeth, as well as throughout the remainder of the structure, for maximum discharge through the valves and over the spillway, except where otherwise noted. Two sets of pressures are shown on the curves; one for normal tailwater, and one for the tailwater elevation 5 feet lower than normal. In general, the lowering of the tailwater reduced the pressures as was to be expected. Also included on Figure 14 are water surface profiles for Designs Nos. 4 and 5 with vertical pool walls. A photograph of the recommended design with both spillway and outlet valves operating at maximum capacity is shown on Figure 12A.

A scour picture of the final design, shown on Figure 12B, represents the scour obtained in the model with maximum flow for two hours corresponding to 14 hours, prototype.

OUTLET WORKS

Recommended Operation

In any stilling-pool where a hydraulic jump is formed, the flow entering the pool must be spread uniformly across the entrance to obtain satisfactory results. With the outlet valves discharging into the pool, the best results were obtained when all five valves were discharging the same amount of water. Under certain circumstances it will not always be possible to obtain symmetrical operation, especially if one or more valves are being repaired during the operating season, or if the required discharge is so low that it is not practical to open all five valves. The intermediate piers between the valves are an aid in stabilizing the pool for unsymmetrical valve operation. However, the following precautions, as determined from the 1:24 model, which was constructed for this purpose, should be taken: First, the discharge from any one valve should not exceed 1,500 second-feet unless all five are operating, then it can be allowed to approach 2,000 second-feet from each valve. This precaution is necessary because of the manifold arrangement by which the valves are connected to the penstock. If all five valves are operated fully open, they will discharge approximately 2,000 second-feet per valve with an effective head of 159 feet immediately upstream from the valves. When one valve is completely closed and the remaining four set fully open, the discharge per valve will increase to 2,215 second-feet and the effective head will be 195 feet. As the process of closing down one valve at a time is continued, the discharge per valve remaining fully open is as follows: Three valves 2,437 second-feet each, two valves 2,650 second-feet each, and one valve 2,805 second-feet, assuming a full reservoir under all conditions. The stilling-pool is not adequate for the higher single valve discharges, and for this reason, it will be necessary to limit the discharge per valve to 1,500 second-feet until all five valves are operating, at which time all of the valves can be operated fully open.

Limiting the discharge per valve to 1,500 second-feet, until all of the valves are discharging restricts the energy of the jets to a value compatible with the capacity of the stilling-pool.

When it is necessary to operate less than five valves, the following combinations are recommended:

One valve--Center valve

Two valves--Valves adjacent to center valves

Three valves--Center valve and outside valves

Four valves--All but center valve

CONCLUSIONS

a. Vertical stilling-pool walls are more satisfactory than sloping walls.

b. Intermediate piers between the valves are necessary for unbalanced valve operation.

c. Apron teeth increase the energy dissipation in a stilling-pool; however, with the high head at Anderson Ranch Dam, they may be subject to cavitational erosion.

d. It will be necessary to limit the discharge per valve to 1,500 second-feet when less than five valves are operating to prevent erosion downstream from the pool.

Table 1

Stilling-pool profile	Valve spacing	Stilling-pool wall slope	Type apron teeth	Type pool sill	Type piers	Remarks
Original	Tilted down 4° 20' crs	1/4:1	-	A	-	Pool not stable with only valves operating. Pool rough at maximum discharge. Scour not excessive.
Original	Tilted down 4° 20' crs	Vertical	-	A	-	Pool more stable with valves only operating. Pool rough at maximum discharge. Scour not excessive.
No. 1	Level at 20' crs	1/4:1	-	A	I	Tested without flow over spillway to find a satisfactory combination of piers and stilling-pool for the valve discharge. Vertical pool walls in combination with Type I piers appeared most satisfactory from these tests.
No. 1	Level at 20' crs	Vertical	-	A	I	
No. 1	Level at 20' crs	Vertical	-	A	-	
No. 1	Level at 20' crs	1/4:1	-	A	-	
No. 1	Level at 20' crs	1/4:1	-	A	II	
No. 1	Level at 20' crs	1/4:1	-	A	III	
No. 1	Level at 20' crs	Vertical	-	A	II	

Table 1 (continued)

Stilling-pool profile	Valve spacing	Stilling-pool wall slope	Type apron teeth	Type pool sill	Type piers	Remarks
No. 1	Level at 20' crs	Vertical	-	A	III	Tested without flow over spillway to find a satisfactory combination of piers and stilling-pool for the valve discharge. Vertical pool walls in combination with Type I piers appeared most satisfactory from these tests.
No. 1	Tilted 2° down	Vertical	-	A	I	
No. 1	Tilted 2° down	Vertical	-	A	II	
No. 1	Tilted 2° down	Vertical	-	A	III	
No. 2	Level at 21' crs	1/4:1	-	A	IV	Vertical walls along trajectory apron. Did not improve flow. Tested to determine effect of an abrupt change in slope at toe of apron on the energy dissipation.
No. 2	Level at 20' crs	1/4:1	-	A	IV	
No. 2	Level at 20' crs	Vertical	A	A	IV	
No. 2	Level at 20' crs	Vertical	-	A	IV	
No. 3	Tilted down 4° 20' crs	Vertical	-	A	IV	Long apron to spread valve jets. Did not increase efficiency.

Table 1 (continued)

Stilling-pool profile	Valve spacing	Stilling-pool wall slope	Type apron teeth	Type pool sill	Type piers	Remarks
No. 4	Tilted down 4° 20' crs	Vertical	-	B	IV	Pool floor lowered 5 feet. This increased the efficiency and was considered the most satisfactory in combination with vertical pool walls, Type C apron teeth, Type D sill, and Type IV piers.
No. 4	Tilted down 4° 20' crs	Vertical	C	C	IV	
No. 4	Tilted down 4° 20' crs	1/4:1	C	D	IV	
No. 4	Tilted down 4° 20' crs	Vertical	C	D	IV	Tested to show deterioration of pool efficiency with an increase in slope of stilling-pool walls. As the slope changed from vertical to 1:1, energy dissipation in the pool decreased. Water surface became rougher with an increase in slope.
No. 4	Tilted down 4° 20' crs	1/8:1	C	D	IV	
No. 4	Tilted down 4° 20' crs	3/8:1	C	D	IV	
No. 4	Tilted down 4° 20' crs	1/2:1	C	D	IV	Tested to show effect of apron teeth. Less energy dissipation without apron teeth.

Table 1 (continued)

Stilling-pool profile	Valve spacing	Stilling-pool wall slope	Type apron teeth	Type pool sill	Type piers	Remarks
No. 4	Tilted down 4° 20' crs	1/2:1	-	D	IV	Tested to show effect of apron teeth. Less energy dissipation without apron teeth.
No. 4	Tilted down 4° 20' crs	1:1	C	D	IV	
No. 4	Tilted down 4° 20' crs	Vertical	-	D	IV	Tested to determine effect of apron teeth. Improvement with apron teeth.
No. 4	Tilted down 4° 20' crs	Vertical	C	D	V	Tests to determine most economical pier of which Type VI was considered most satisfactory.
No. 4	Tilted down 4° 20' crs	Vertical	C	D	VI	
No. 4	Tilted down 4° 20' crs	Vertical	C	D	VII	
No. 4	Tilted down 4° 20' crs	Vertical	C	D	VIII	

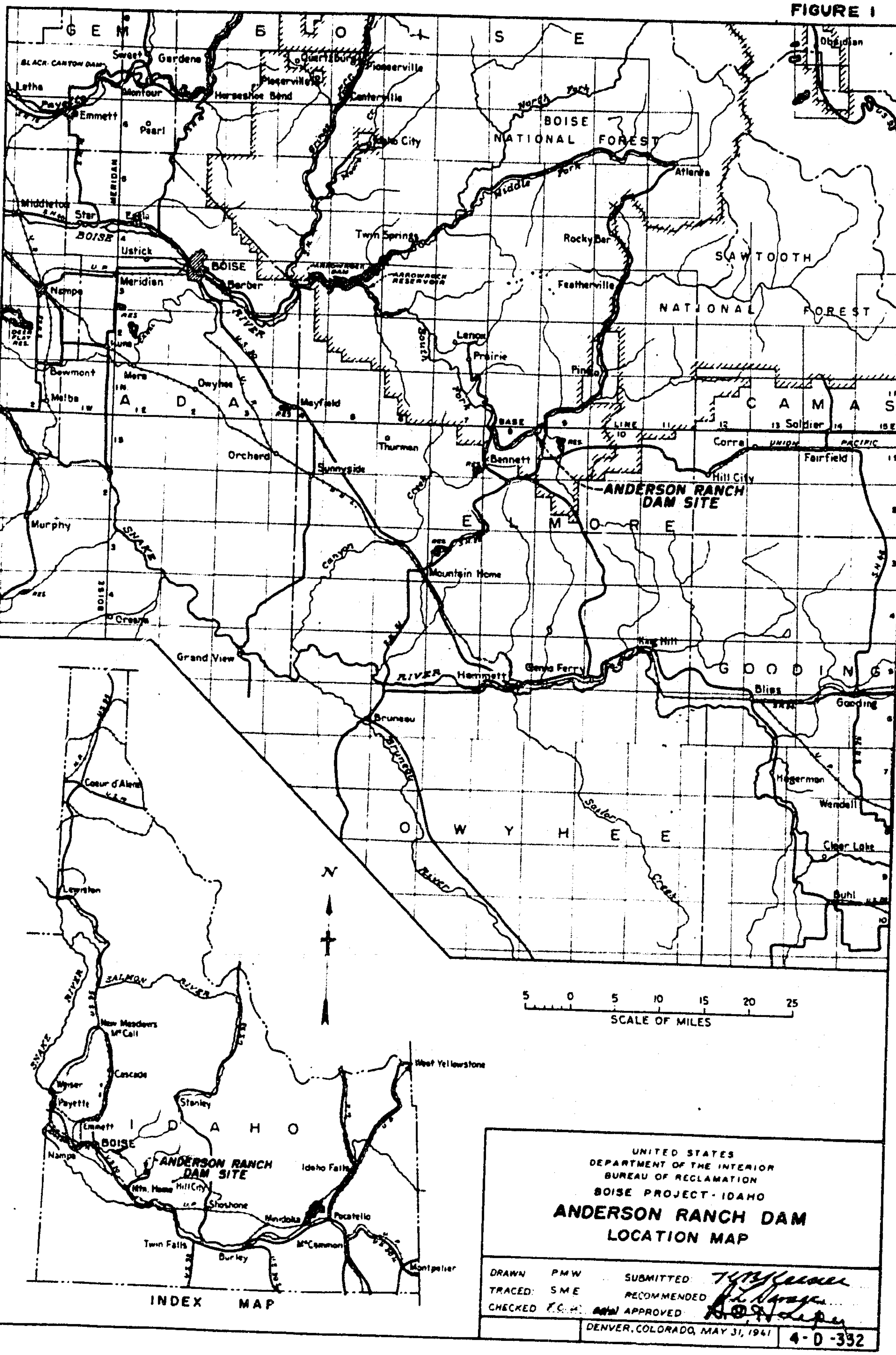
Table 1 (continued)

Stilling-pool profile	Valve spacing	Stilling-pool wall slope	Type apron teeth	Type pool sill	Type piers	Remarks
No. 4	Tilted down 4° 20' crs	Vertical	C	D	IX	Tests to determine most economical pier of which Type VI was considered most satisfactory.
No. 5	Tilted down 4° 20' crs	Vertical	-	D	IV	Tested to determine if abrupt change in apron would improve efficiency. No improvement and break in grade was a potential source of cavitation.
No. 5	Tilted down 4° 20' crs	Vertical	B	D	IV	
No. 6	Tilted down 4° 20' crs	Vertical	-	D	IV	Tested to determine if longer horizontal part of pool would improve flow. No improvement.
No. 6	Tilted down 4° 20' crs	1/4:1	D	D	IV	
No. 6	Tilted down 4° 20' crs	Vertical	D	D	IV	
No. 6	Tilted down 4° 20' crs	1/4:1	-	D	IV	

Table 1 (continued)

Stilling-pool profile	Valve spacing	Stilling-pool wall slope	Type apron teeth	Type pool sill	Type piers	Remarks
No. 7	Tilted down 4° 20' crs	Vertical	C	D	IV	Tested to determine if it was possible to obtain satisfactory results with pool floor at elevation 3835.0. Also to compare results with tests on pool Profile No. 4. The 5-foot difference in elevation caused the jump to sweep out at much lower tailwater elevations.
No. 7	Tilted down 4° 20' crs	1/4:1	C	D	IV	

FIGURE 1



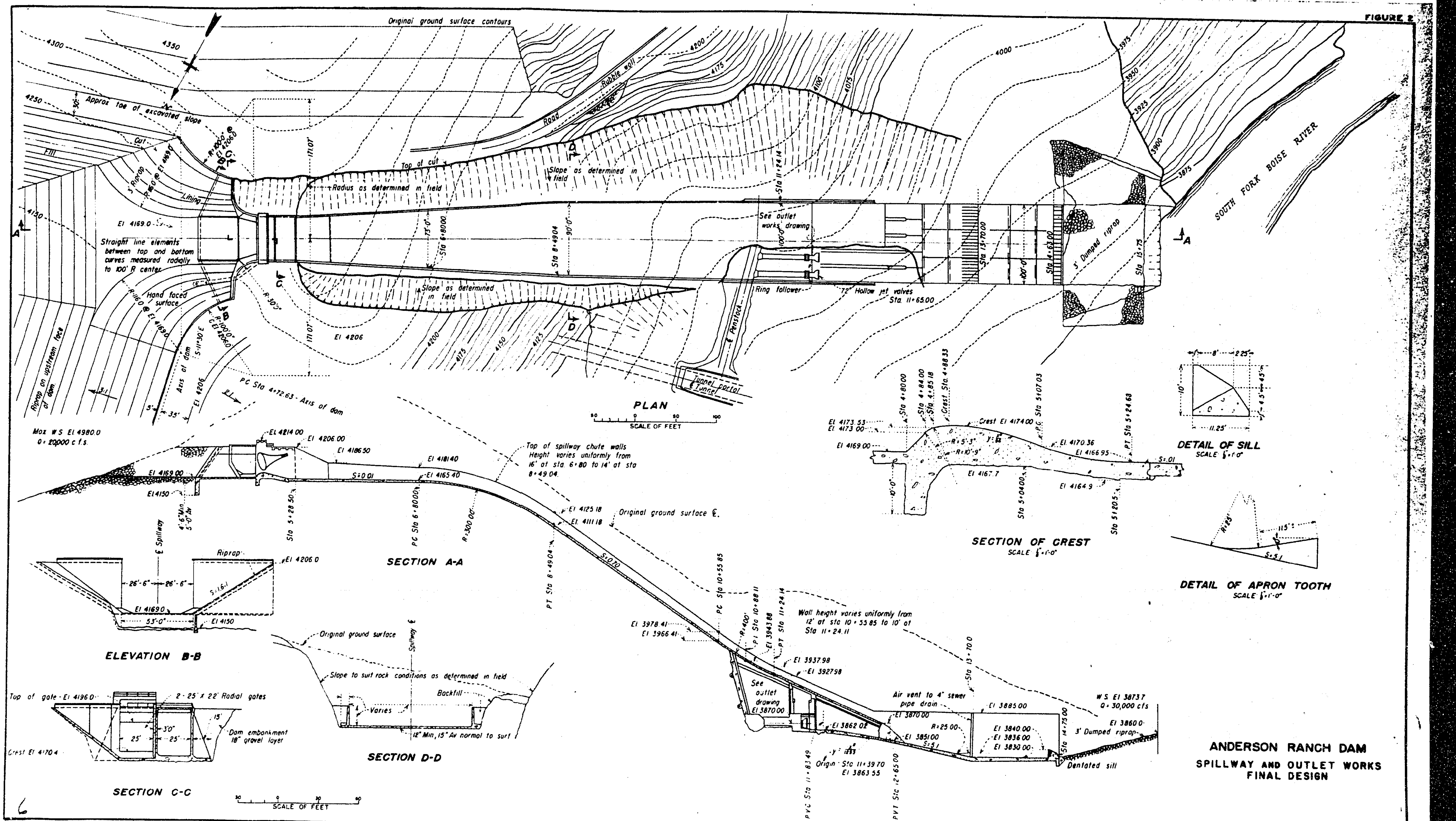
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
BOISE PROJECT - IDAHO

ANDERSON RANCH DAM
LOCATION MAP

DRAWN	P.M.W.	SUBMITTED	[signature]
TRACED	S.M.E.	RECOMMENDED	[signature]
CHECKED	F.C.H.	APPROVED	[signature]

DENVER, COLORADO, MAY 31, 1941 — 4-D-332

FIGURE 2

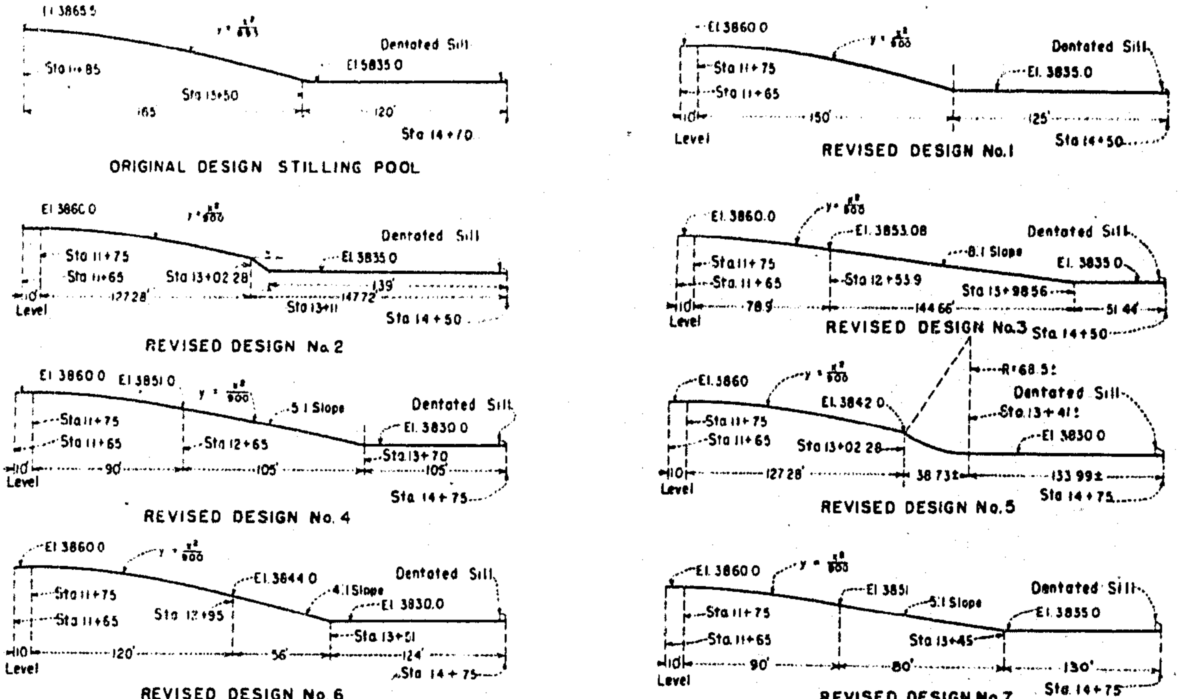


ANDERSON RANCH DAM

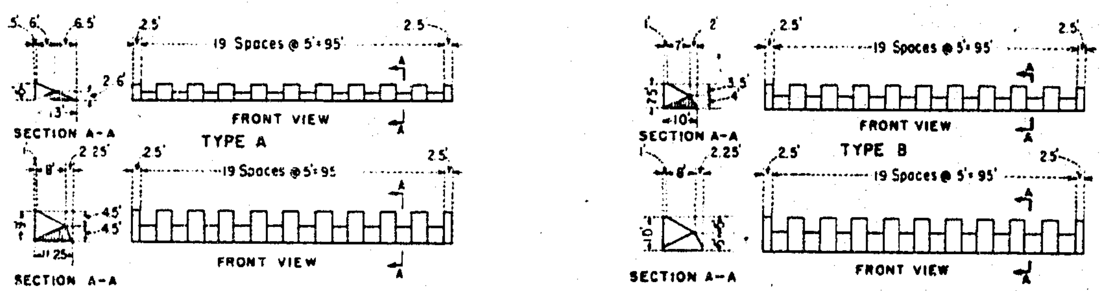
SPILLWAY AND OUTLET WORKS

FINAL DESIGN

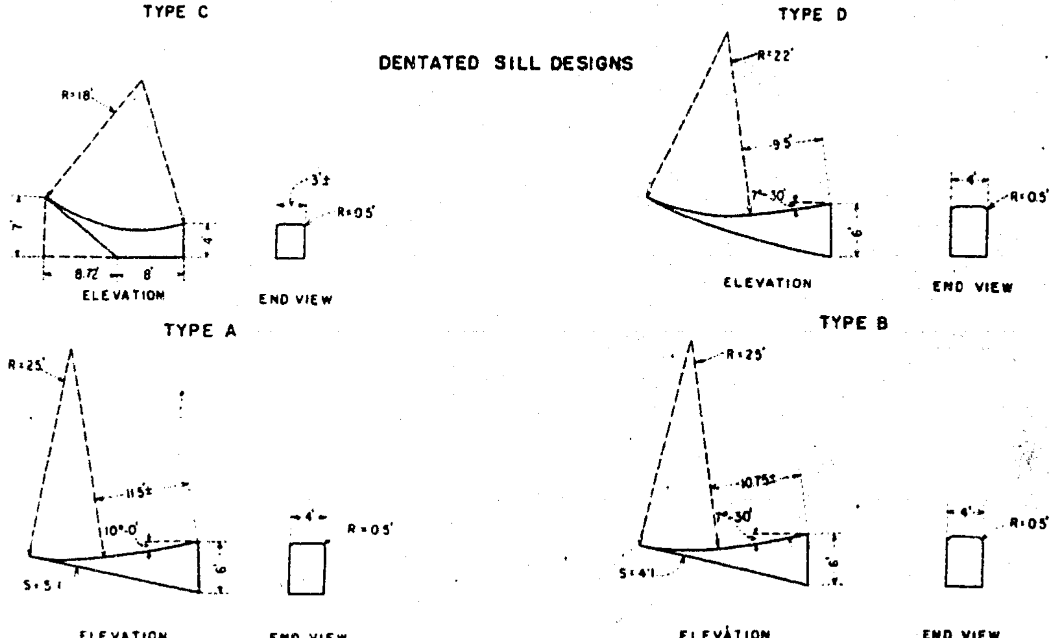
6



STILLING POOL DESIGNS



DENTATED SILL DESIGNS

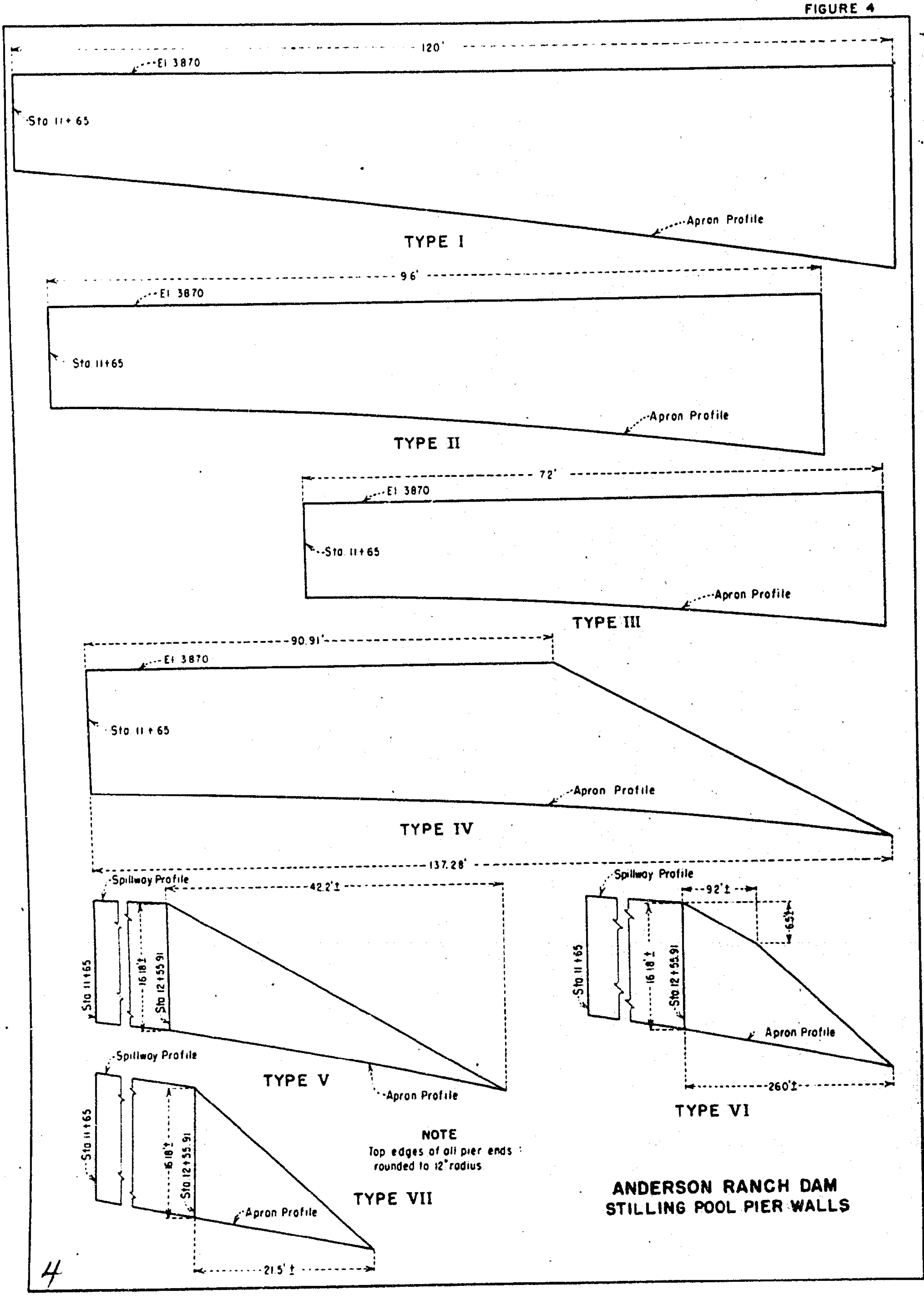


APRON TEETH DESIGNS

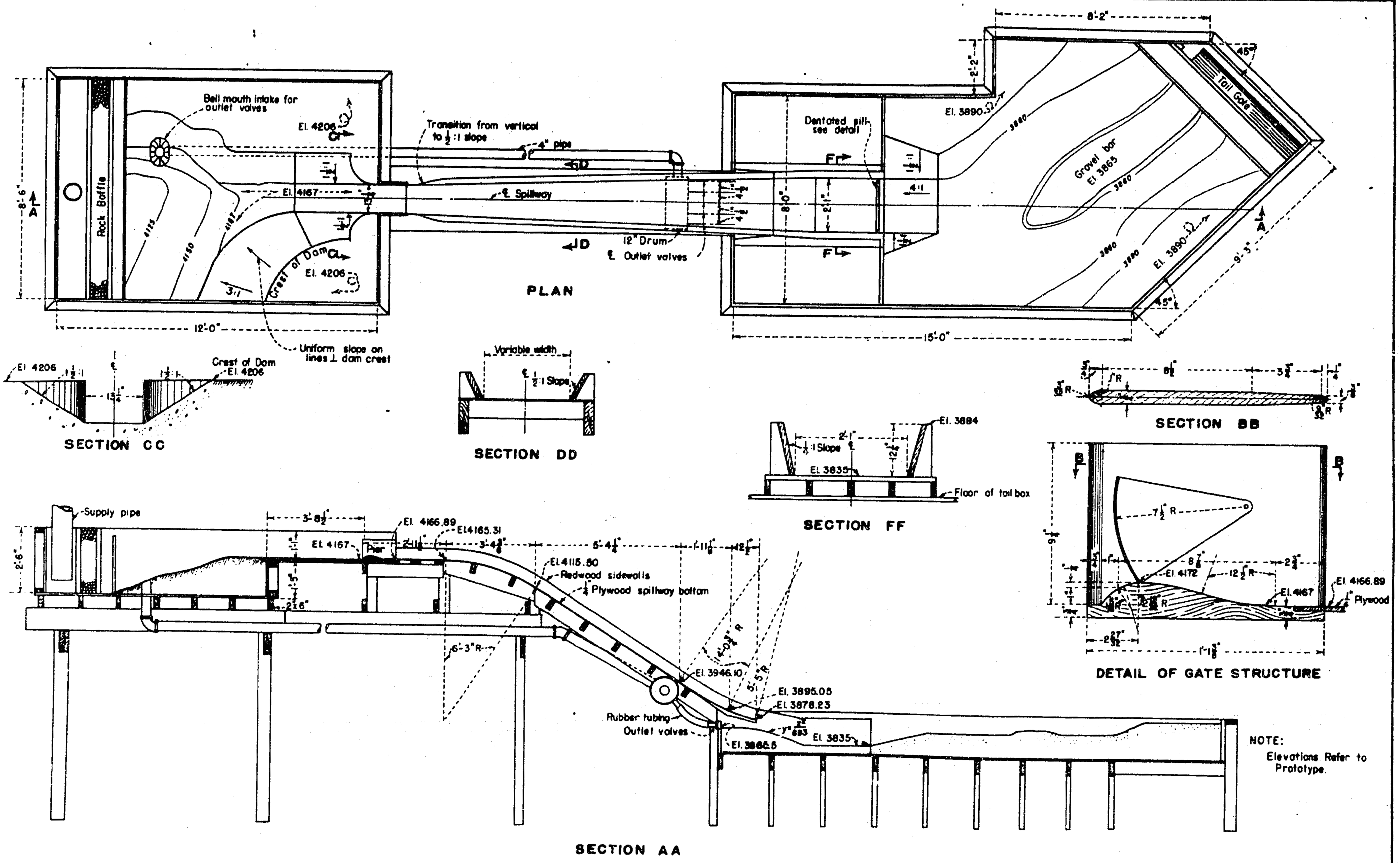
ANDERSON RANCH DAM

STILLING POOL AND SILL DETAILS

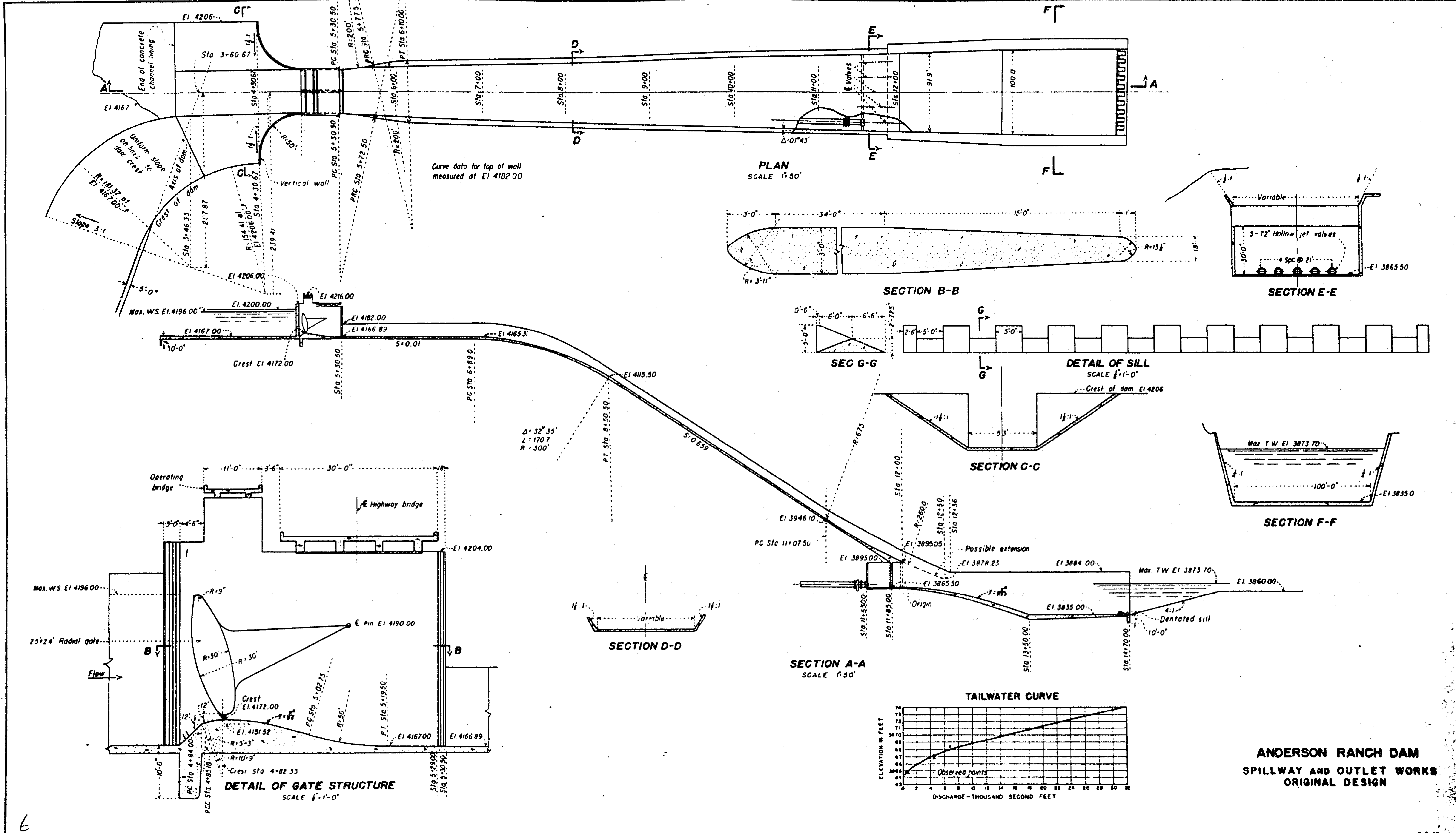
FIGURE 4



ANDERSON RANCH DAM
STILLING POOL PIER WALLS

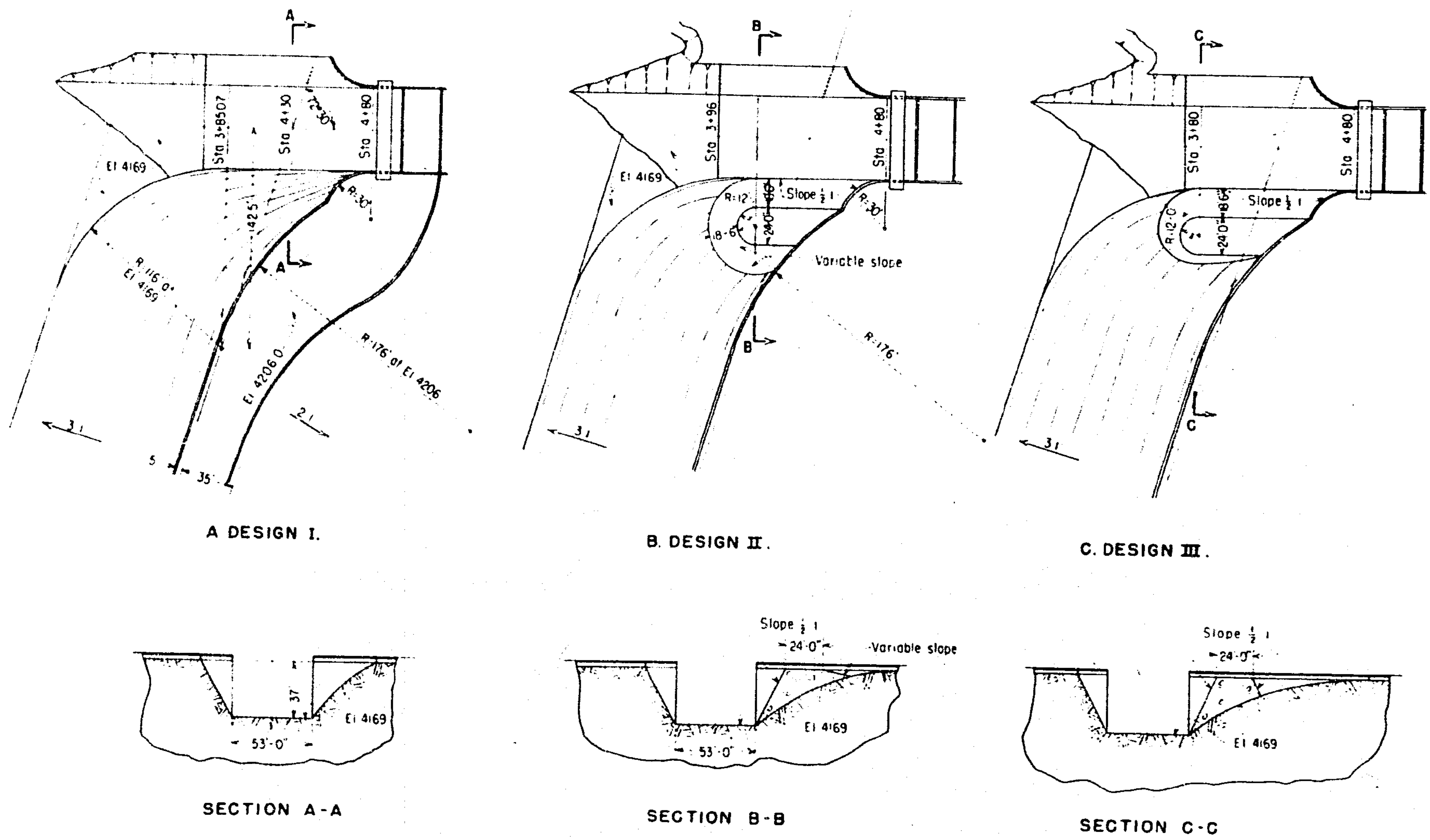


ANDERSON RANCH DAM SPILLWAY AND OUTLET WORKS
DETAILS OF 1:48 SCALE MODEL



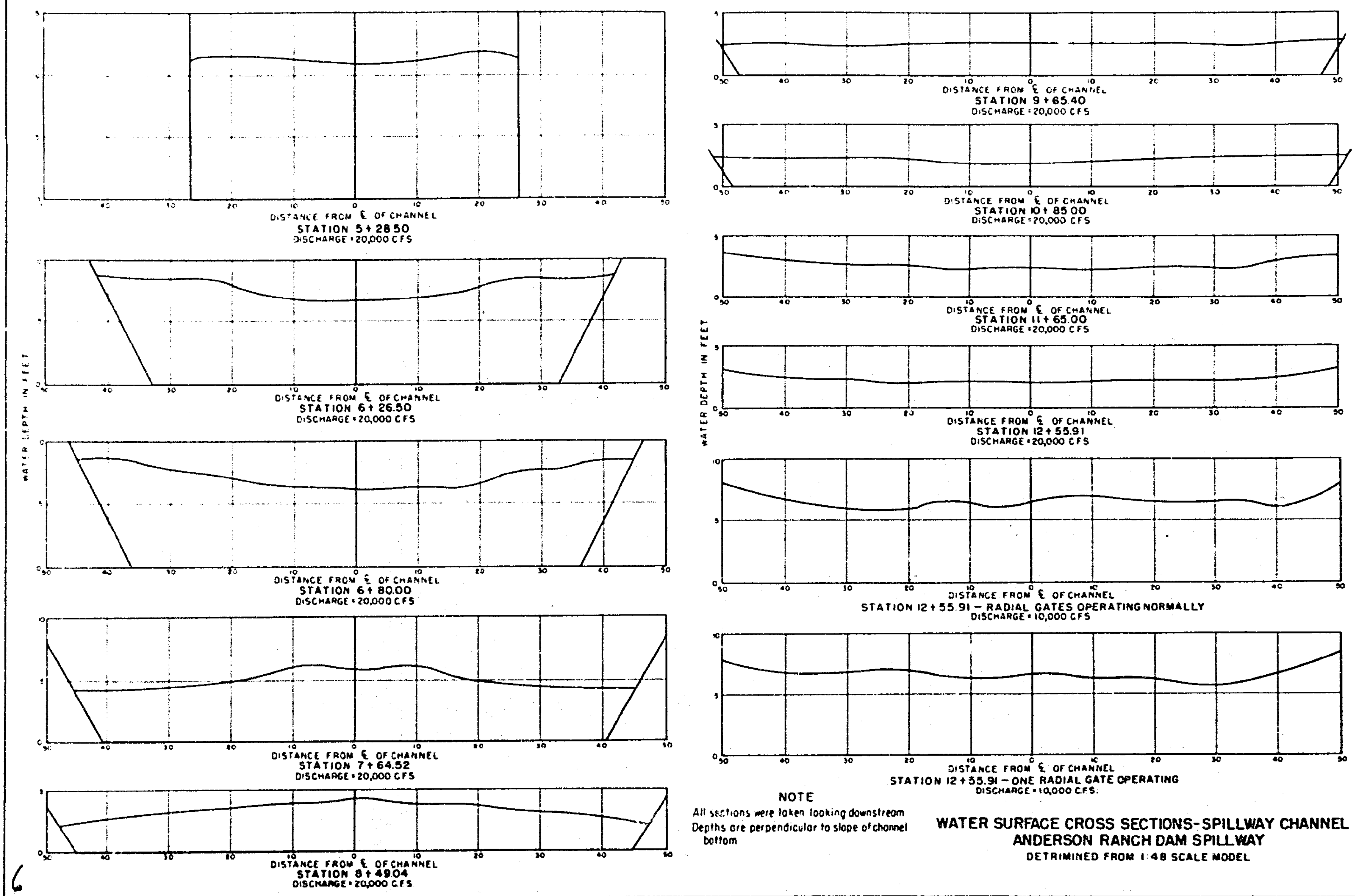
ANDERSON RANCH DAM
SPILLWAY AND OUTLET WORKS ORIGINAL DESIGN

6



ANDERSON RANCH DAM
SPILLWAY ENTRANCES
TESTED IN A 1:48 SCALE MODEL

FIGURE 7



NOTE

All sections were taken looking downstream
Depths are perpendicular to slope of channel bottom

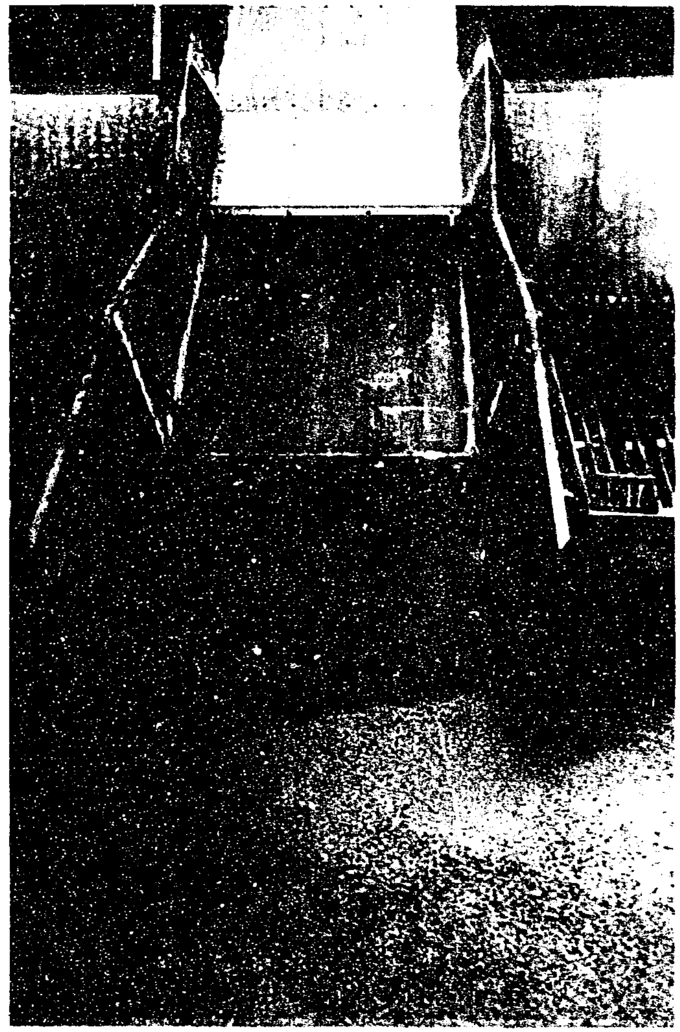
FIGURE 8

WATER SURFACE CROSS SECTIONS-SPILLWAY CHANNEL
ANDERSON RANCH DAM SPILLWAY
DETRIMINED FROM 1:48 SCALE MODEL

6

FIGURE 9

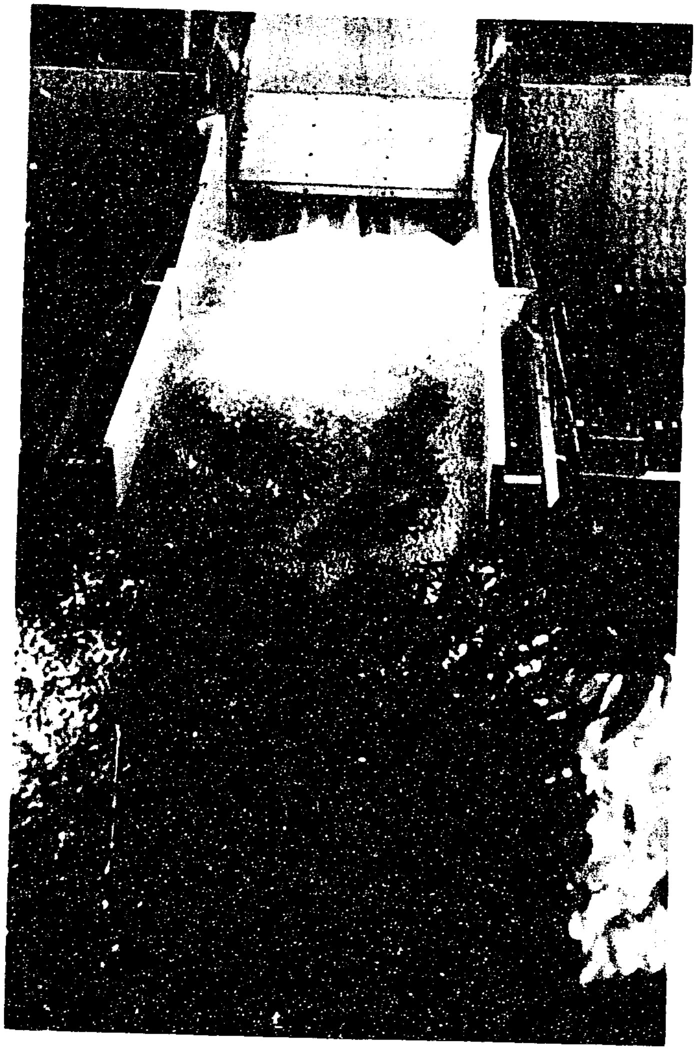
A. Maximum discharge of 10,000 second-feet from five outlet valves.



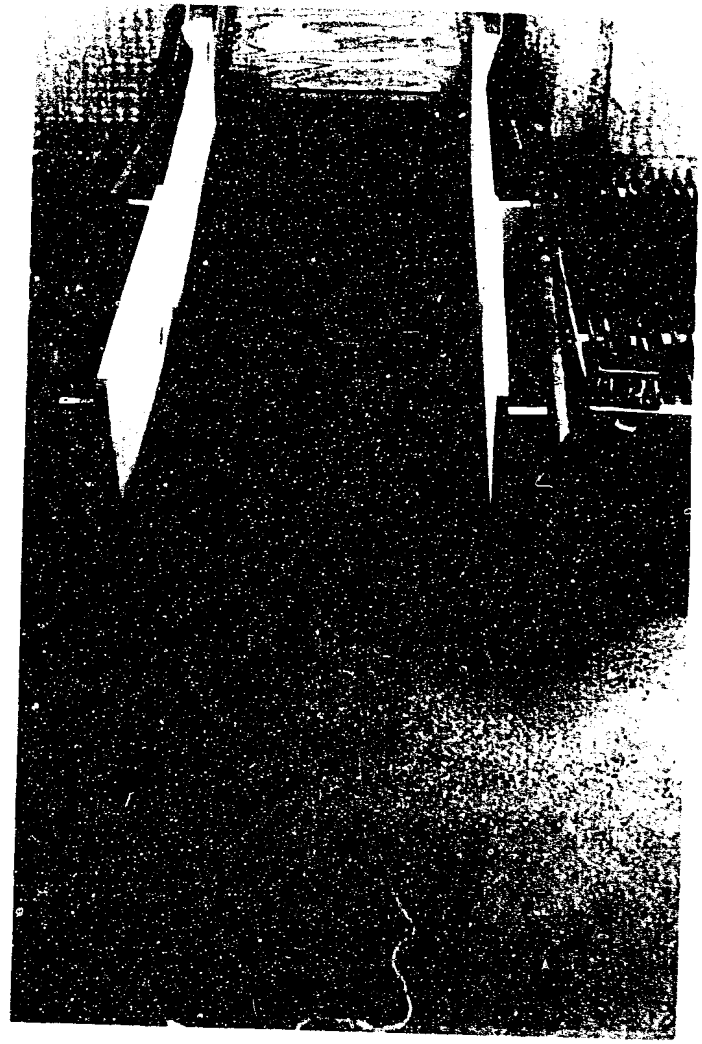
B. Scour after maximum flow of 30,000 second-feet from spillway and outlet valves.

ORIGINAL DESIGN

FIGURE 10



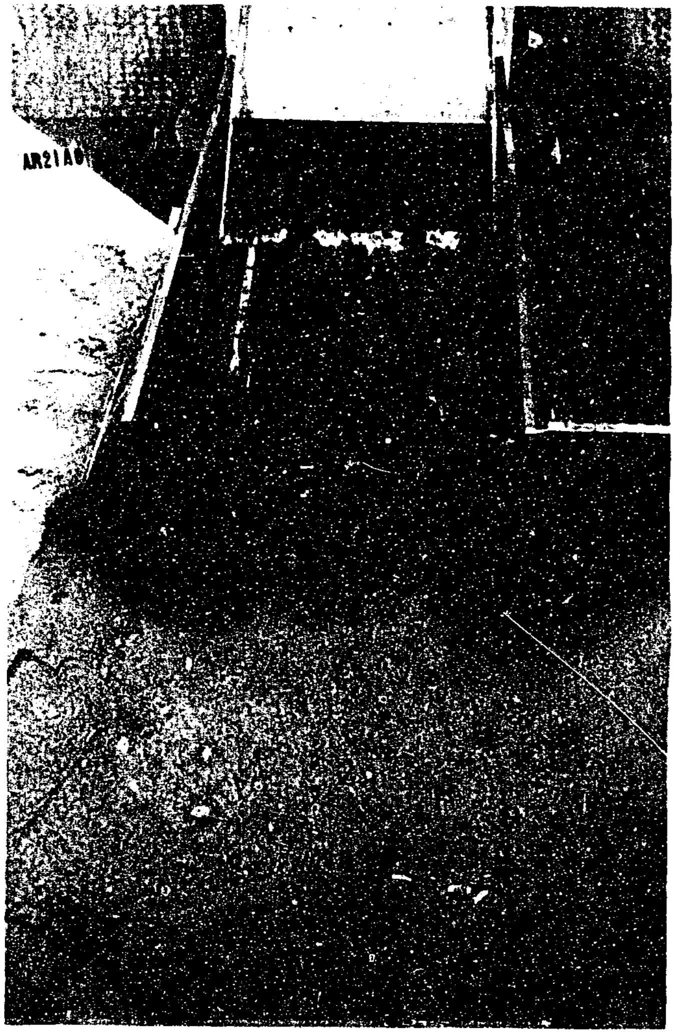
A. Maximum discharge of 10,000 second-feet from 8 valves.



B. Scour after flow of 30,000 second-feet.

ORIGINAL DESIGN WITH VERTICAL POOL WALLS

FIGURE 11

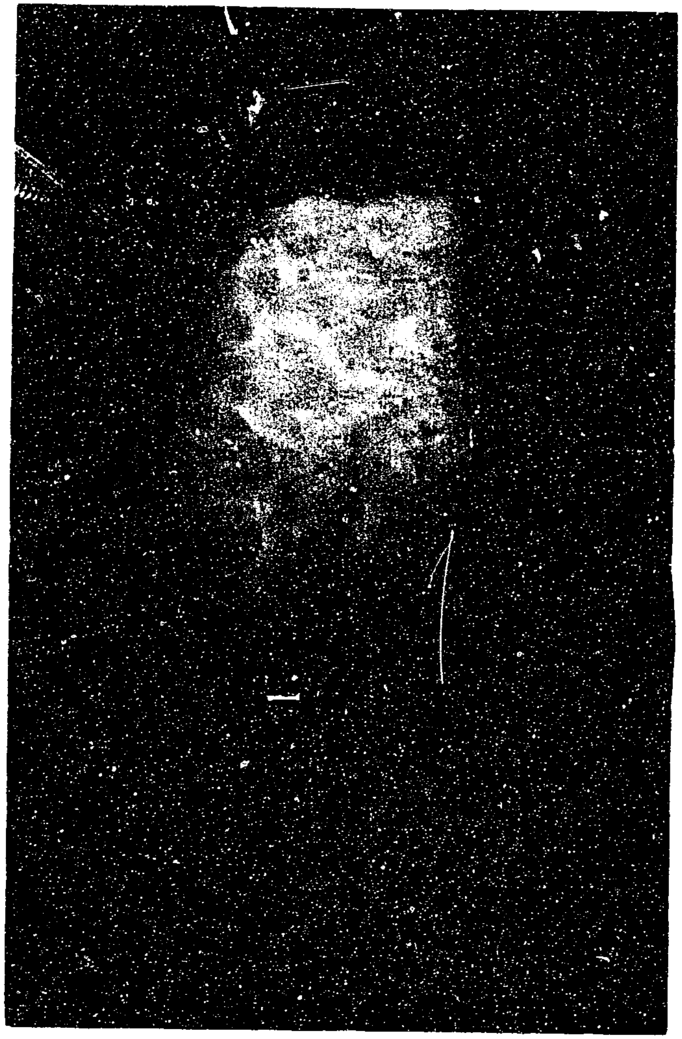


A. Stilling-pool Design No. 4.

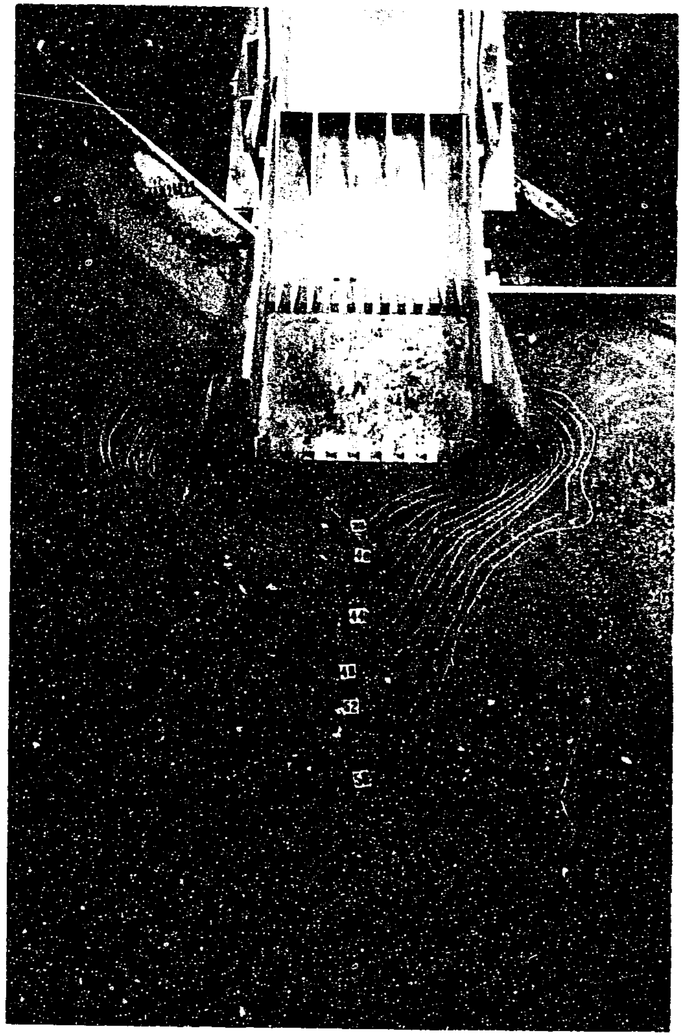
B. Maximum discharge of 10,000 second-feet from five outlet valves.

TENTATIVE FINAL DESIGN

FIGURE 12



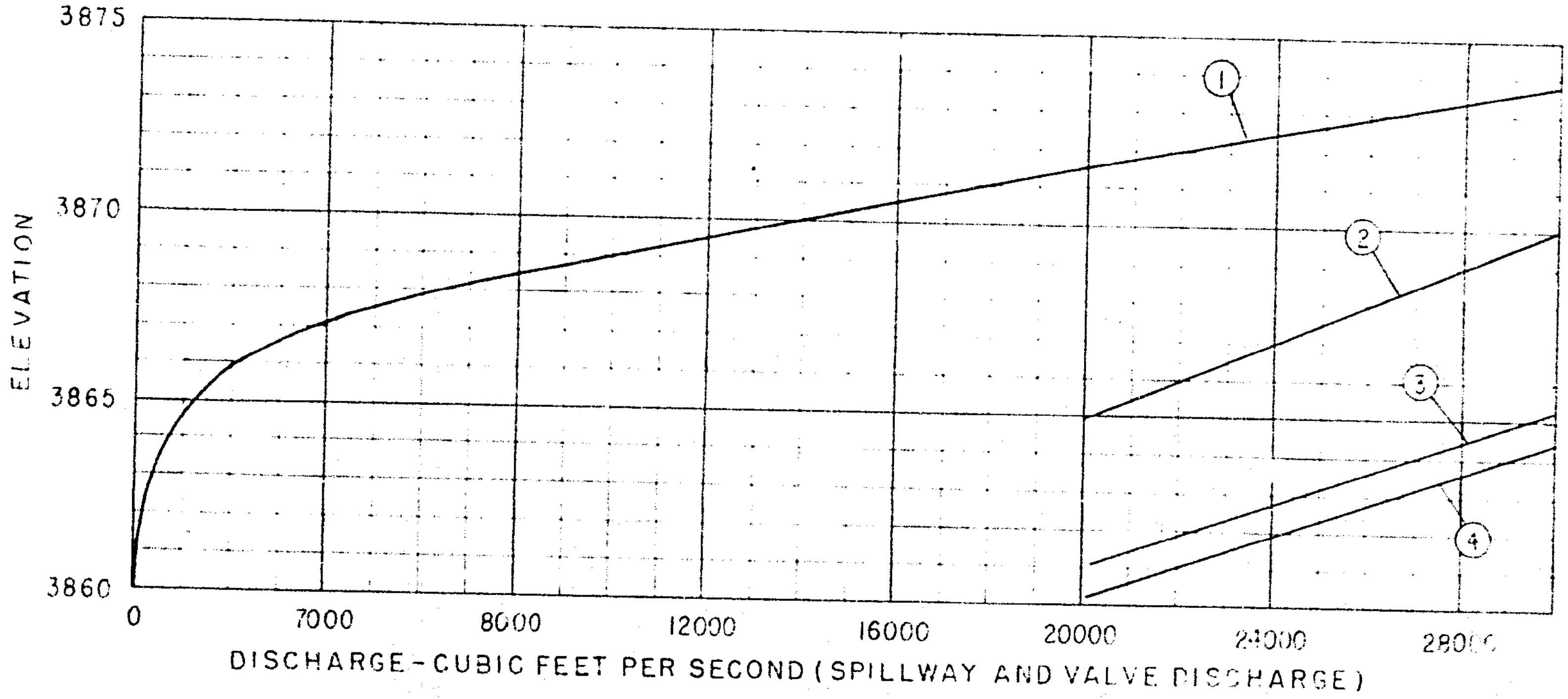
A. Maximum discharge 30,000 second-feet. Spillway and outlet valves discharging.



B. Scour after two hour run (model) of 30,000 second-feet.

RECOMMENDED DESIGN

FIGURE 13



(1) Normal tailwater curve.

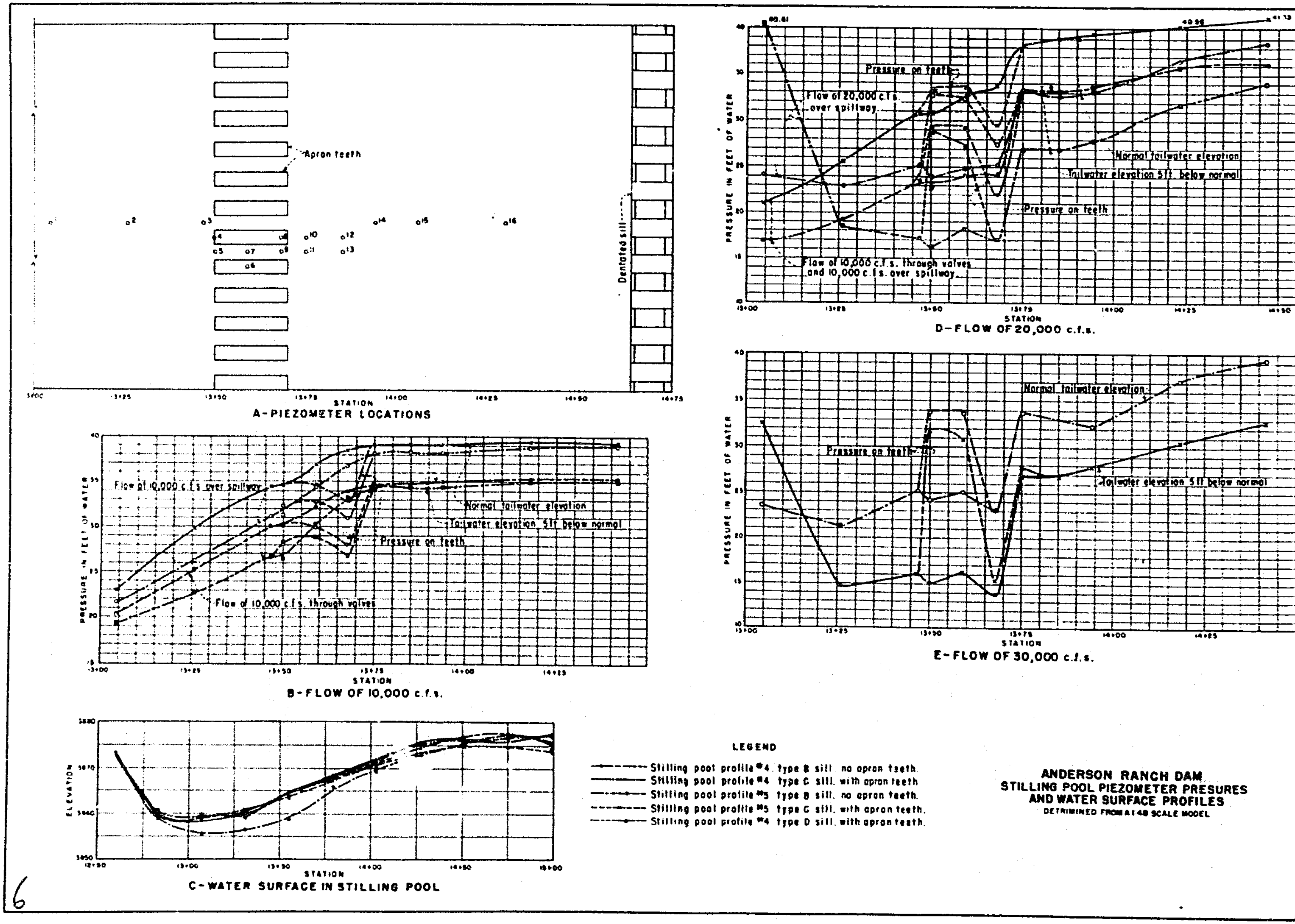
(2) Elevation at which jump sweeps out (stilling pool profile #7 with type D sill and apron teeth).

(3) Elevation at which jump sweeps out (stilling pool profile #4 with type D sill and no apron teeth).

(4) Elevation at which jump sweeps out (stilling pool profile #4 with type D sill and apron teeth).

ANDERSON RANCH DAM
SWEEP OUT CURVES

6



ANDERSON RANCH DAM
STILLING POOL PIEZOMETER PRESURES
AND WATER SURFACE PROFILES
DETRIMINED FROM A 1:48 SCALE MODEL

FIGURE 14